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THE MACHINES THAT DRAW—A REVIEW

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ABSTRACT

Since the industrial revolution after the Second World War, machines have been used for various activities to increase productivity. But rarely machines have been used to produce or reproduce art, as people think it needs creativity to create or reproduce art. In this age of artificial intelligence it is possible to create and reproduce art using machines. The present study discusses about having an overview of the evolution of machines that draw, techniques used in it, and the fields in which this is used.

KEYWORDS: Drawing Robots, Intelligent Machines, Kinematics & Machines for Art

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A REVIEW

INTRODUCTION

Designing a machine that draw is a challenging work as it requires very high precision and necessarily fast. So that the efficiency of the machine stays high. What made the scientists to stay away from inventing a machine to draw is the fear of missing minute details in a drawing. But from the idea of scientists of the twentieth century, it has come a long way to make dreams into reality.

DATA ACQUISITION

Acquiring data from the primary source has been different. Few scientists acquired data from an already existing art, whereas few scientists acquired real time data by recording an image on the spot.

Caricature Generator

He also examined the perceptual phenomena regarding individuating features. His study involved some surveys regarding the automatic and man-machine systems which represent and manipulate the face. He implemented an algorithm to refine a human face in a computer generated caricature. He is the first person to suggest Caricature as an application in interactive graphic interfaces. The diagram for the exploration strategy [1] is shown in the Figure 1.

Kuipers et.al [1] performed experiments with a simulated robot in multiple two dimensional environments. He analyzed this method to be robust and very efficient for exploration, mapping and navigation of robots in a large-scale environments. In addition to exploration and building maps in a complex environment, the approach also provides an ideal way to manage the effect of sensory errors. To achieve this, a critically acclaimed exploration strategy has been used by him.

Suk-Swan Suh et.al [3] worked in robot motion planning to find an integrated scheme of robotic painting operation. He developed an Integrated Robot Painting System (IRPS). The IRPS used part geometry, painting mechanics and robot kinematics to automatically generate efficient robot trajectories.

Shiraishi et.al [4] presented a method for the automatic painter drawing an image with a hand drawn look from a source image such as a photograph.

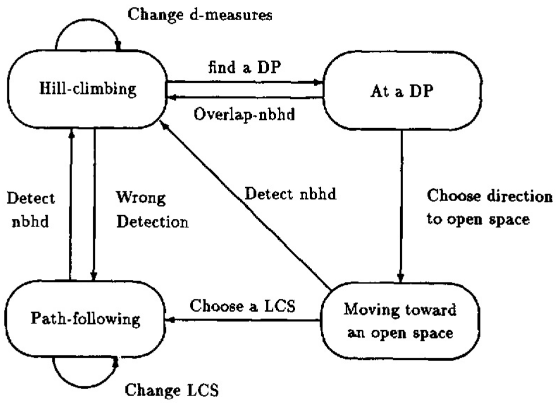


Figure 1: State Event Diagram for Exploration Strategy [1]

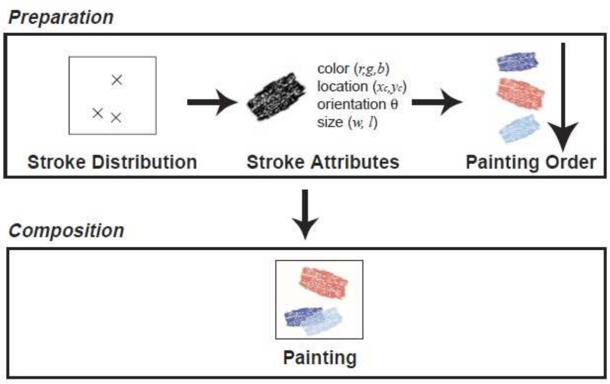


Figure 2: A Process of Painterly Rendering [4]

The differences between the local source images and the stroke colors are taken and then calculated with the image moments of the color difference images. This method works with the intensity and chromaticity of the original image. The flat regions in the output image is painted with large strokes from which the painting starts and minute details are painted with smaller strokes in which the painting completes. The density is provided with curves. This process of painting is shown in Figure 2.

Figure 3: ISAC Humanoid Drawing Robot [5]

Srikaew, A., et al.[5] worked with a Dual Armed Humanoid Robot named ISAC which observes an artist and follows the physical actions of the artist to draw the image. ISAC would not produce the same original image, but an image which would be possible for the physical action of the artist. So, the artist could possibly add-on the variations to make the image better. A humanoid service robot designed for entertainment differs significantly from an industrial robot. Such a robot must physically interact with a human being. Therefore, it must be safe; its design must minimize the possibility of injuring a person. A humanoid robot will not be of much use if programmed to perform a fixed set of relatively simple, repetitive tasks. It must take commands from a person to perform a wide variety of complex tasks, each of which could be unique to the moment. Not only must it be purposive to accomplish specific tasks, but also it must be exible and reactive to cope with a highly dynamic environment. Such reactive exibility requires the use of complex sensing such as 3D vision, force feedback, and touch. Sensing, at this level, involves much more than the gathering of sensory information. It involves the understanding of sensory information within the context of the problem at hand. In those ways, a human service robot must be able to sense and act much like a human being. There are many examples of robots being used for entertainment. The movie industry uses animatronics to bring to life the fantasies of writers in movies such as Jurassic Park. There are several examples of robots playing musical instruments [3, 4], however, drawing robots are rare. An example of a drawing robot is ARRON [6]. ARRON is the creation of Dr. Cohen at the University of California at San Diego. It is a highly developed drawing machine capable of creating impressive drawings. ARRON consists of 2 parts. First, an artificial intelligence program creates a drawing in software. This drawing could be printed or displayed on a monitor. The second part of the system is a Cartesian robot that draws the picture. The Cartesian robot is basically a plotter. However, the interaction between the artist and ARRON only occurs at the source code level. Another example of a drawing robot is Drawbot which uses a small industrial robot to draw pre-programmed shapes such as a simple star.

[19] RAP [Robotic Action Painter] is an important robot which exhibits randomness, stigmergy and chromotaxis. RAP is wild as random and responsible with feedback. To determine the scene, especially the presence, shape and intensity of the color, RAP uses nine RGB sensors. RAP identifies patterns, which helps the robot to determine the end of the process.

[12] Researchers presented a control method for a robotic arm to let the robot to draw. Here, MATLAB is used for image processing and trajectory calculation and Sobel and Canny are applied for edge detection method. Using inverse kinematics, co-ordinate position of a pixel of binary image is converted into joint angle. The comparison of outputs after applying sobel and canny are demonstrated.

[13] This robot uses acrylic paint on canvas. The robot has an arm which paints which is accompanied by a machine learning alogorithm to calculate the sequence of brush strokes to convert an electronic image date to an art. Brush types and stroke parameters are determined by the artists along with the palette. The machine learning algorithm used helps in tuning the parameters of the algorithm and back propagates to adjust the weights. Later the original image and drawn image is compared using a genetic algorithm.

[15] An optimal trajectory model has been developed by Diao et.al to optimize the trajectory planning on a free surface for the deposition uniformity over a painted surface and reduce the wastage of coating materials. Numerical solution techniques consider four parameters for the same: a) geometric characteristics on a free surface, b) rate of film accumulation, c) position and orientation of spray guns in uniformity coating and d) painting duration. Nonlinear programming techniques based difference quasi-Newton method over cone surfaces has been used given a specified spatial

path and functions of film accumulation rates for an infinite range model and a beta distribution model, which provided objective functions that can be used to minimize the thickness variation of the paint.

[16] A human portrait generation system has been developed that enables the two-armed humanoid robot, to draw the face portrait of the person sitting in front of the robot autonomously. The robot has been named as Pica. The portrait generation system converts a face image captured by the CCD camera installed on the head of Pica, two line segments that constitute a portrait of a good artist quality and are suitable for the robotic arm to draw within a short period of time. A selected reduced number of pixel points on the line segments of the portrait are used to control the motion of the robot arm. The control points on the portrait plane are then automatically transformed into the robot's coordinates. A PD controller drives the motors of the robot arm to complete the real-time portrait drawing and signature.

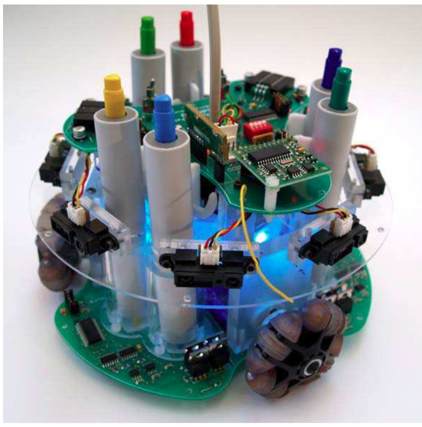


Figure 4: Robotic Action Painter [19]

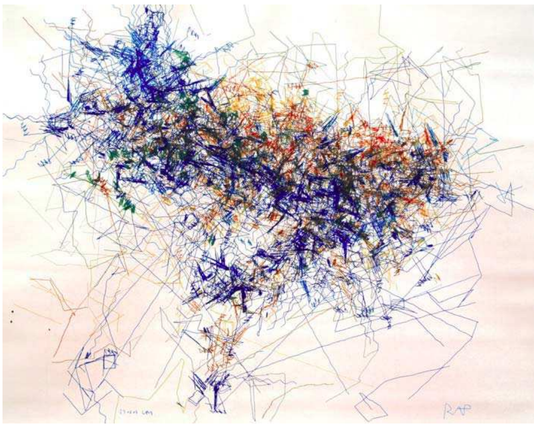


Figure 5: A painting by Robotic Action Painter [19]

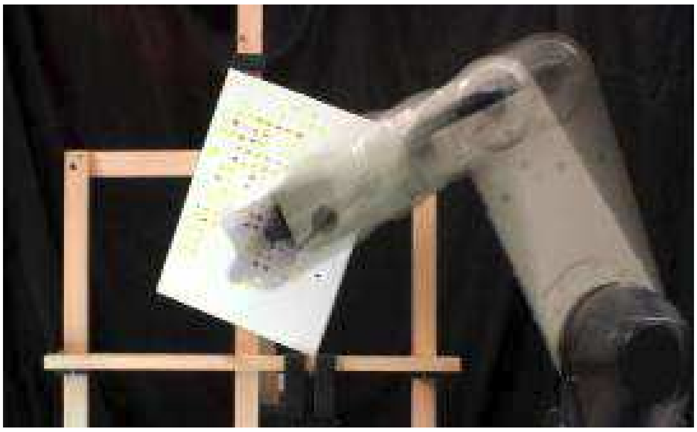


Figure 6: An Articulated 6DOF Arm Holding a Paint to Brush a 23 x 30cm Canvas [13]

[8] A novel robot has been designed to be attached with a support commercial truck, which can paint the pavement lane. The inspection of the pavement lane is done by an image processing algorithm that can find eroded lane marks. This is an easy set up that even a cab driver without a prior knowledge of painting can do it as the image processing algorithm identifies the eroded lane marks and do the work for him. This work extracted real time data from real pavements for the project.

[14] Automated tool path planning methods have been developed to replace manual tool path planning methods. This improved the efficiency as well as reduced the cost.

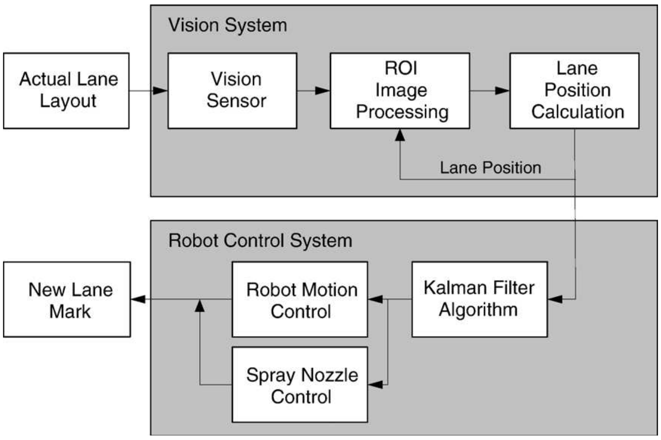


Figure 7: Block Diagram of Lane Painting Robot System[8]

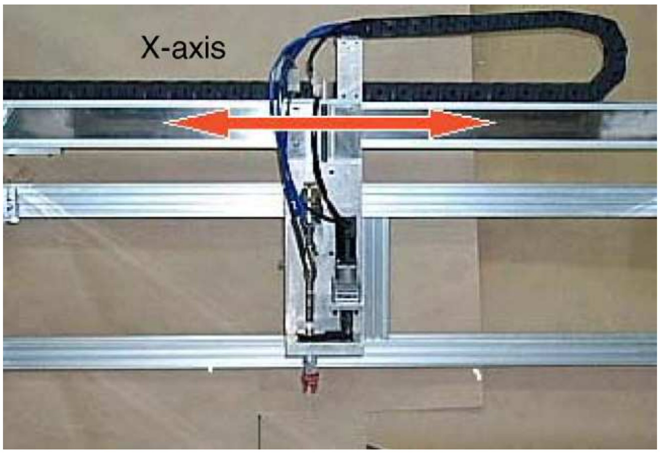


Figure 8: Robot and Paint Nozzle Assembly [8]

Spray painting is a significant process in product development and manufacturing. The quality of the product can be highly influenced by the uniformity of the paint thickness. There are two ways used in tool path planning: manual and automatic. In manual method a conventional teaching method is exerted, which depends on the technician's skill. Computer aided tool path planning will take data from CAD model automatically and plan the tool path.

This review discussed major issues like:

- Path generation
- The CAD model formats
- Material Deposition Pattern
- Tool models
- Automated paint path planning methods
- Paint deposition simulation methods.

[7] This paper describes the real-time capturing and data analysis of the brush footprint using a robot drawing platform supporting four degrees of freedom (x, y, z and z-rotation) of a brush-pen motion. This robot is used for studying Chinese language and caligraphy. They embrace a clear drawing plate and beneath camera system, at the side

of projective rectification and video segmentation algorithms. Preliminary results of the footprint analysis and statistic modeling, and their applications to well-known Chinese script are exhibited.

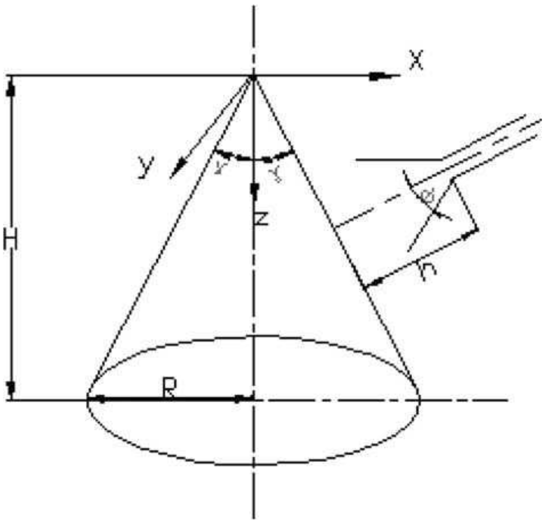


Figure 9: Hardware Design of a Drawing Robot [7] **Figure 10: Painting on a Cone Work Piece [15]**

[14] The scientists developed a trajectory model to control the path planning on a surface to attain even deposition over any painted surface and thereby reducing the wastage of coating materials. When a specified target path, functions of film collection rate and beta distribution function are provided, quasi-newtonian are used to get the results of the values of functions to minimize the thickness variation of the paint. The results obtained is a generalized one and can be used in other non-linear problems.

[20] The control architecture of a portrait drawing robot called DrawBot is developed. The drawbot reproduces the visuomotor behaviour of a human. Computational models of eye movements in human beings, and eye-hand coordination is used in the above visuomotor technique.

[21] Creating a portrait in the style of a particular artistic tradition or a particular artist is a difficult problem. Elusive to codify algorithmically, the nebulous qualities which combine to form artwork are often well captured using example-based approaches. These methods place the artist in the process, often during system training, in the hope that their talents may be tapped. Example based methods do not make this problem easy, however. Examples are precious, so training sets are small, reducing the number of techniques which may be employed. We propose a system which combines two separate but similar subsystems, one for the face and another for the hair, each of which employs a global and a local model. Facial exaggeration to achieve the desired stylistic look is handled during the global face phase. Each subsystem uses a divide-and-conquer approach, but while the face subsystem decomposes into separable subproblems for the eyes, mouth, nose, etc., the hair needs to be subdivided in a relatively arbitrary way, making the hair subproblem decomposition an important step which must be handled carefully with a structured model and a detailed model.

[22] The authors considered the problem of generating art with a computer system, as it relates to the understanding of a drawing style. The system was able to sketch faces automatically, starting from a picture, typically a photographic snapshot of a scene with humans. Once a digital image was considered, the system automatically found where some of the faces (or face-like patterns) were and isolated them. Each face image pattern was used to produce a stylized portrait. The style which the system aims at using is derived from the one the first author has developed over the

years in his artistic practice. The goal is for the final system to mimic the process developed by the artist, rather than aiming at results exactly reproducing his way of drawing a portrait. Nevertheless, the produced sketches are in the style of the artist. Various steps in the process of producing a sketch by the artist were isolated, including: image segmentation, filtering, shape selection and depiction, filling and shading. The implementation of these steps relies on an understanding of human visual perception, of the artist's work process, and of advances made in computer vision.

[11] A robot is designed that draws with regular marking pens on piece of paper. The robot uses PIC microcontroller and three servo motors for the joints. Two separate sub-systems are combined to form a system, for the face as well as hair. The system extracts and combines two types of edges: geometry edges obtained from polygonal data, and photometry edges obtained from a rendered image. Both of them are observed from a virtual viewpoint. The system extracts and combines two styles of edges: geometrical edges obtained from plane figure information, and visuometric edges obtained from a rendered image. Each of them are observed from a virtual viewpoint. Then they are applied to a textured 3D polygonal human model and verified for appropriate feature lines.

[28] Scientists' developed a robot system, which has developed the ability to draw faces from a photo of a scene with human itself. When a photo with a scenic background is provided, the algorithm finds the faces in the image and a beautiful portrait is produced. The aim of the project was to mimic an artist's work. Meanwhile during the process of producing the portrait various steps like image segmentation, filtering, shape selection and depiction, filling and shading were eliminated.

[17] The dual armed robot PIC draws the portrait of the person sitting in front of it. The face image is converted into line segments to be processed. The highlight of this work is the quality and speed of operation of this robot. Few pixel points are used as control elements of the robot arm which are then automatically transferred into robot's co-ordinates. A proportional derivative controller is used for the operation of the robot.

[18] A wall-climbing robot for painting the hull surface has been designed by the researchers. The robot walked with caterpillar, permanent adsorption and driven by AC servo motor, the paint system was controlled by solenoid valve and pressure pump. Control system uses the supervisory computer and lower computer of two-stage distributional control mode and the robot itself is equipped with a visual system to observe the spot of spray paint conveniently. At last through the calculation of two spray path, find the best path and simulation, results show that the robot can realize the function of spray paint better preferable.

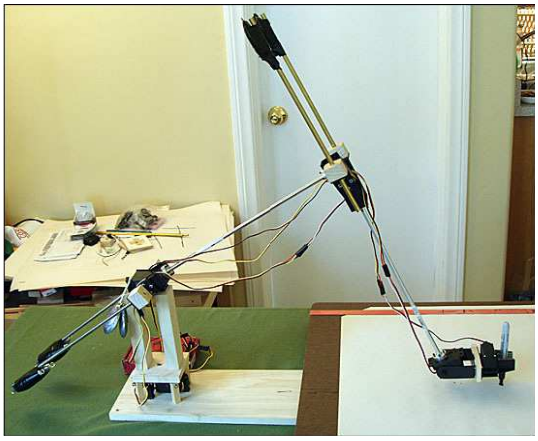


Figure 11: Drawbot [20]

[10] A visual perception discovered in high-level manipulator planning for a robot to reproduce the procedure involved in human painting has been implemented in this research. First, a technique of 2D object segmentation has been applied that considers the region similarity as an objective function and edge as a constraint with artificial intelligent used as a criterion function. Second, a novel color perception model that shows similarity to human perception has also been proposed. Third, a novel global orientation map perception using a radial basis function has also been proposed. Finally, the derived model along with the brush’s position- and force-sensing to produce a visual feedback drawing has been used. Experiments show that this system could generate good paintings including portraits.

Figure 12: Shading Process Example [28]

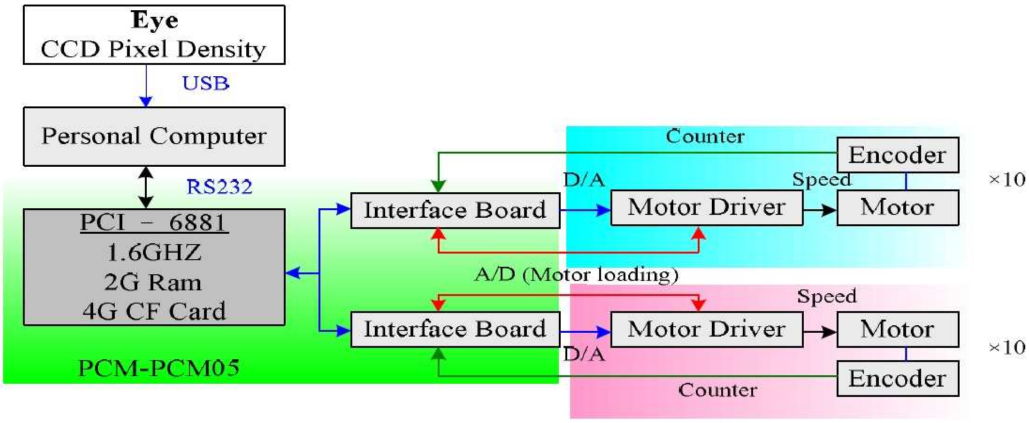


Figure 13: System Structure [17]

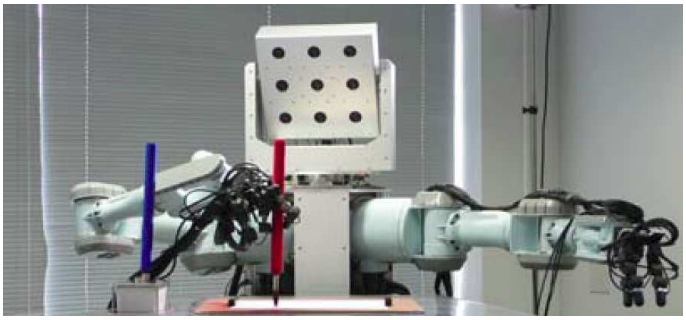
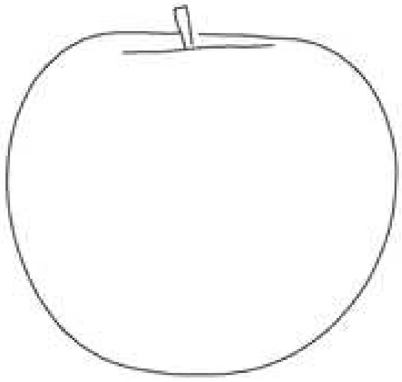


Figure 14: Humanoid Robot Painter [30]



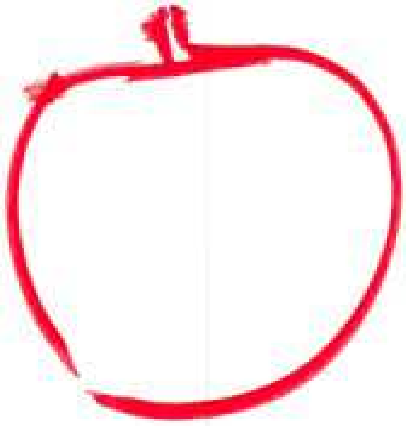


Figure 15: Input Processed by the Algorithm[30] **Figure 16: Output**

[23] A new approach to realize grasping of an unknown object by a dexterous hand robot among freely placed multiple unknown objects even if they are occluded each other has been described. This technology consists of major three functions: 1) image-based 3D reconstruction and separation of multiple objects using graph-cut theory, 2) recognition of the shape, size and orientation of each object as an object with primitive shape, i.e. either of box, cylinder or sphere, 3) multi-goal and multi-criteria path planning for 7 DOF arm with 13 DOF dexterous hand using enhanced RRTs (Rapidly-Exploring Random Trees) algorithm to cope with multiple possible grasping strategy according to the object shape and orientation.

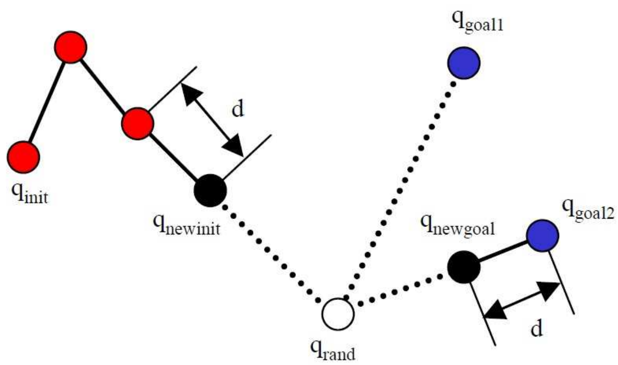


Figure 17: The Tree Generation Technique for Path Planning[31]

[9] A painting robot with multi-fingered hands and stereo vision has been demonstrated. The goal of this study was for the robot to reproduce the whole procedure involved in human painting. A painting action was divided into three phases: obtaining a 3D model, composing a picture model, and painting by a robot. In this system, various feedback techniques including computer vision and force sensors are used. As experiments, an apple and a human silhouette were painted on a canvas using this system.

[24] A robotic system that can perform automated pen-and-ink drawing based on visual feedback, using a proposed algorithm for stroke trajectory planning has been proposed. The algorithm first converts the outlines of an input image to stroke trajectory according to the structural importance. Then, iterative hatching is carried out to convey both the tone and textures of the original image; in this process, visual feedback is employed to determine stroke positions, and local gradient interpolation is applied to guide stroke orientations.

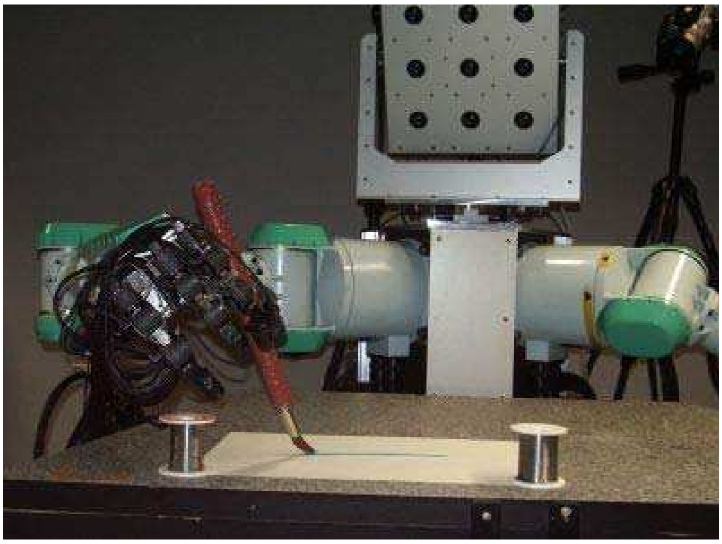


Figure 18: Multi-Fingered Painting Robot [9]

[25] A visual perception discovered in high-level manipulator planning for a robot to reproduce the procedure involved in human painting has been proposed. First, a technique of 3D object segmentation that can work well even when the precision of the cameras is inadequate has been proposed. Second, a simple yet powerful fast color perception model that shows similarity to human perception has been applied. Third, a global orientation map perception using a radial basis function has been generated. Finally, the derived foreground, color segments, and orientation map were used to produce a visual feedback drawing.

[26] The goal of this project was to design a drawing mobile robot, which should replace or reinforce the virtual turtle used in the Logo programming language. The mobile robot Robotnacka is designed to support educational process in connection with flexible environment Imagine for Logo programming language. The central concept of the environment is the virtual turtle, which is programmed by the user.

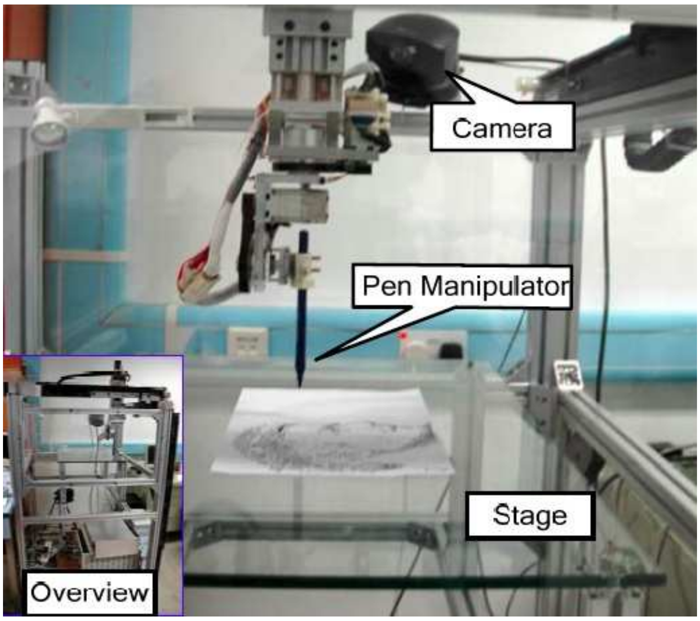


Figure 19: IRAS Drawing Robot Platform [24]

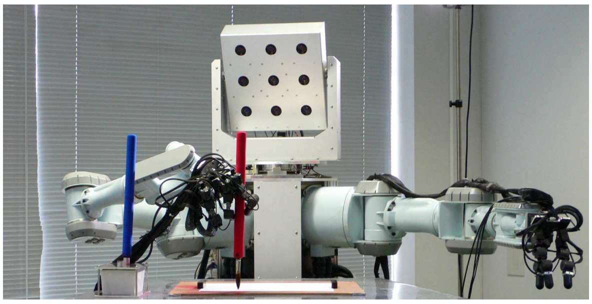


Figure 20: Humanoid Robot Painter: Dot- Chan [25]

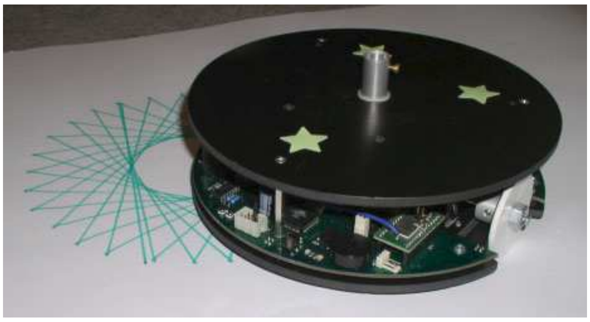


Figure 21: Stars Drawn by Robotnacka, the Drawing Robot [26]

The mobile robot Robotnačka is a physical representation of this turtle, and brings the educational process into a new dimension, adds the real-world experience. The mobile autonomous robot Robotnacka is shown in figure 1. It is a very accurate mobile two-wheel differential driven robot controlled by a simple 8-bit microcontroller. It can be remotely controlled over Bluetooth radio connection from a workstation. The robot is equipped with interchangeable pen, thus enabling drawing pictures on the paper or whiteboard.

[27] Senster, which is one of the primary robotic architectures, which is computer controlled has been built by Edward. Complex surface geometries are a major challenge in providing paint uniformity when spray painted, which also challenges in generating optimization trajectories. A quadratic function has been created to solve the problem and successfully implemented.

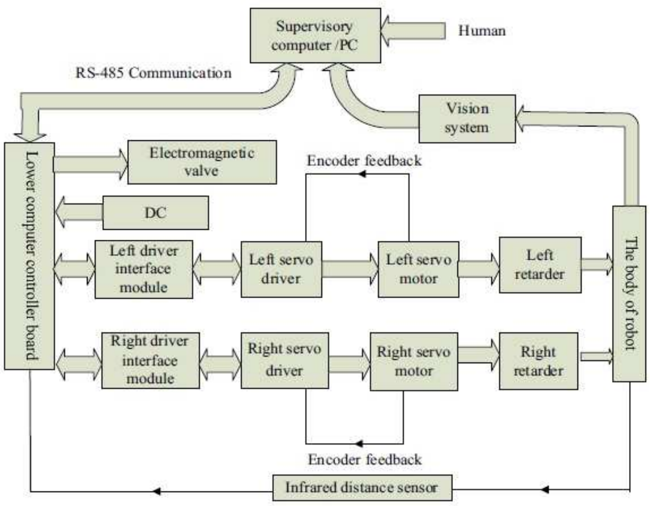


Figure 22: Block Diagram of Control System of Painting Wall Climbing Robot [18]

The proposed algorithm is a genetic algorithm, which resulted in better speed optimization, good convergence properties, and comparatively low computational load.

[28] A robot drawing platform supporting five degrees of freedom (x, y, and z translation, z-rotation, and pitch) of a brush-pen movement was partially developed. The platform was aimed at the acquisition, learning, and execution of human techniques in Chinese brush pen painting and calligraphy. Both replication of existing works and rendition of new styles are planned.

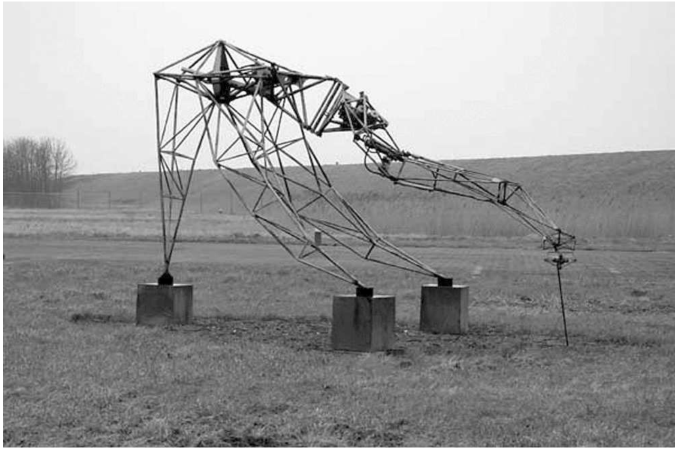


Figure 23: SENSTER [27]

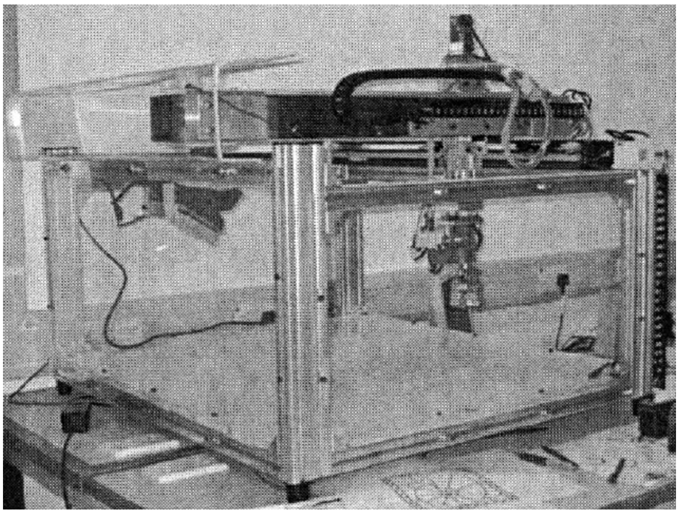


Figure 24: Hardware Design of the Drawing Robot [28]

[29] A 3 DOF robotic arm used for drawing on a paper sheet has been developed. The robotic arm is constructed using LEGO NXT bricks. The purpose was to create a control system of the servo motors for the robot, as well as the inverse kinematics, used for moving the arm. The NXT controller is running LejOS for optimal motor control, while inverse kinematics is being calculated on a PC connected to the NXT via Bluetooth. The robotic arm can be applied in education projects about robotics and robot programming.

[30] A system which exploits a cognitive architecture in order to implement a creative painting mechanism in a humanoid robot such as the Aldebaran NAOR has been proposed. The system is capable of autonomously assessing its own work during the portrait creation process. The system output is ready to be converted in a set of NAO arm gestures.

This would let the NAO robot capable of drawing a portrait by waving some sort of virtual pen in the air. The NAO gestures will be captured through an infrared acquisition system and interpreted as being movements of a brush on a canvas. The results will be continuously evaluated and compared with the internal model of portrait in order to decide how to complete the painting. This approach will realize an autonomous dynamic improvement process, and not a mere planning painting procedure.

[31] A robot equipped with force sensing capability that can draw portraits on a non-calibrated, arbitrarily shaped surface has been demonstrated. The robot is able to draw on a non-calibrated surface by orienting its drawing pen normal to the drawing surface, the penjs-orientation being computed from the forces being sensed. In this way, the robot is also able to draw portraits on arbitrarily shaped surfaces without knowing the Surface geometry. This avoids the need for calibration of robot. With respect to the drawing surface. A number of portraits were drawn successfully on a flat surface without calibration. Also a map outline was drawn on a spherical globe to demonstrate the ability of robot to draw on an arbitrarily shaped surface.

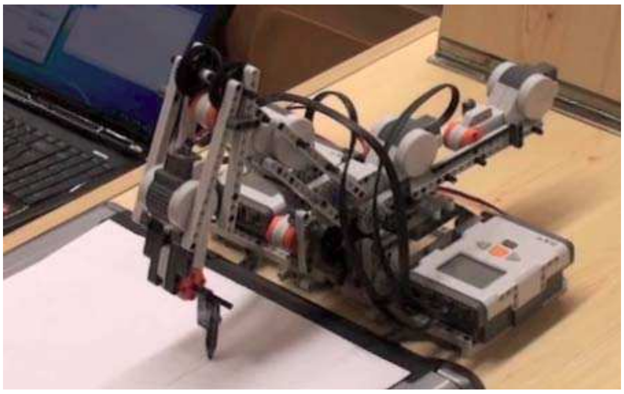


Figure 25: The Robot Arm is Drawing a Rectangle [29]

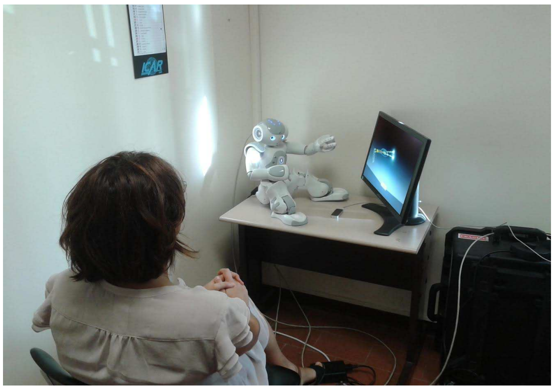


Figure 26: Portrait Execution [30]

[32] The problem of estimating ideal edges joining points in a pixel reduction image for an existing point to point portrait drawing humanoid robot, Betty has been examined. To solve this line drawing problem a modified Theta-graph, called Furthest Neighbor Theta-graph, which we show is computable in O (n (log n)/θ) time, where θ is a fixed angle in the graph's definition has been presented. The results show that the number of edges in the resulting drawing is significantly reduced without degrading the detail of the final output image.

Figure 27: Force-Controlled Robotic Drawing Setup [31]

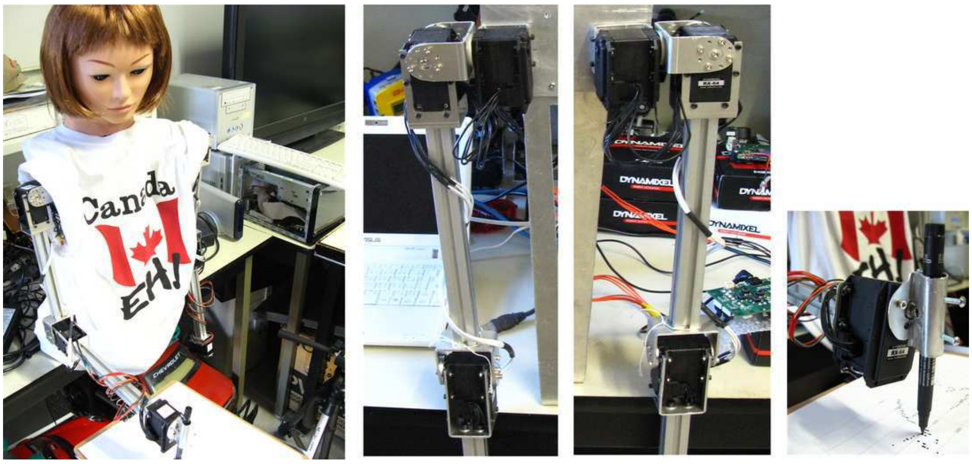


Figure 28: Betty - The 12-DOF Humanoid Robot Artist [32]

[33] A behavior-based robot control method of brush drawing has been presented. Differential movement was adopted instead of traversal points. Simulation verifies the feasibility of behavior-based robots drawing. Simulation and experiment proved that behavior-based robots brush drawing scheme is superior.

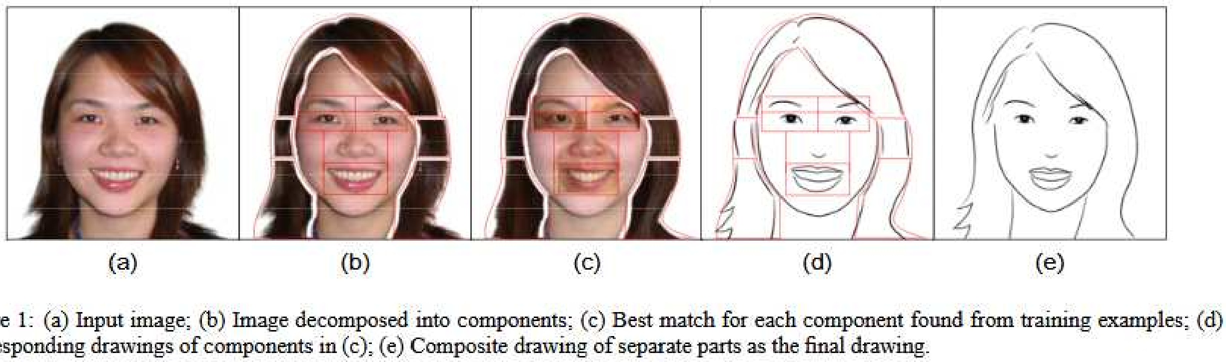


Figure 29: Processing Steps [21]

[34] A conceptual framework for a philosophical discussion of this question regarding the status of machine art and machine creativity has been offered by the scientists. They also discuss theory in aesthetics, refers to literature on computational creativity, and contributes to the philosophy of technology and philosophical anthropology by reflecting on the role of technology in art creation. The discussion was also about considering non-human forms of creativity, and not only cases where either humans or machines create art but also collaborations between humans and machines, which makes human-technology relations better.

[35] A Polygonal Approximation is performed on a picture taken from a webcam with a desirable amount of points, this with the purpose to have an optimal representation of the drawing. The image is pre-processed with different methods like canny edge detection and threshold with dilation operators before Polygonal approximation begins. After pre-processing is finished, the algorithm for the approximation is carried out; once we have the N points that best describe the contour of the figure, the coordinates are stored and a 2 dof arm draws the contour of the figure observed.

Figure 30: Robotic Arm [35]

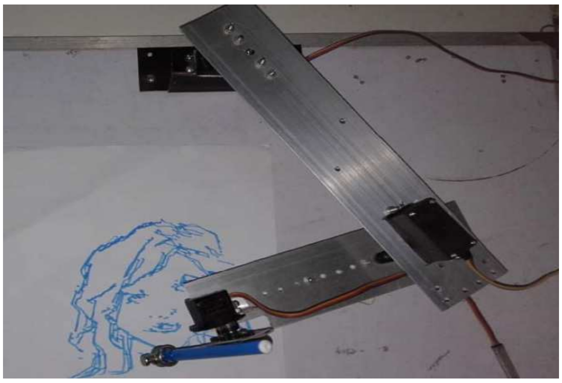


Figure 31: Robot Drawing Image [12]

CONCLUSIONS

Various methods and set up of machines to draw has been discussed. It has been evident from the above discussion that machines with higher degrees of freedom provide a fine output. It is also proven that drawing the edges have been challenging for the end-effector due to few constrains, where the mechanical constraints are primitive. The vision algorithms also play a vital role in identifying the edges. Sobel and Canny are the two dominant edge detection algorithms used for detecting the edges.

REFERENCES

1. *Kuipers, Benjamin, and Yung-Tai Byun. "A robot exploration and mapping strategy based on a semantic hierarchy of spatial representations." Robotics and autonomous systems 8.1 (1991): 47–63.*
2. *Brennan, Susan Elise. Caricature generator. Diss. Massachusetts Institute of Technology, 1982.*
3. *Suh, S-H., et al. " A prototype integrated robotic painting system: software and hardware development." Intelligent Robots and Systems' 93, IROS'93. Proceedings of the 1993 IEEE/RSJ International Conference on. Vol. 1. IEEE, 1993.*
4. *Shiraishi, Michio, and Yasushi Yamaguchi. "An algorithm for automatic painterly rendering based on local source image approximation." Proceedings of the 1st international symposium on Non-photorealistic animation and rendering. ACM, 2000.*
5. *Srikaew, A., et al. "Humanoid drawing robot." IASTED international conference on robotics and manufacturing. 1998.*
6. *Cohen, Harold. "The further exploits of AARON, painter." Stanford Humanities Review 4.2 (1995): 141–158.*
7. *Lo, Ka Wah, et al. "Brush footprint acquisition and preliminary analysis for chinese calligraphy using a robot drawing platform." Intelligent Robots and Systems, 2006 IEEE/RSJ International Conference on. IEEE, 2006.*
8. *Woo, Sangkyun, et al. "A robotic system for road lane painting." Automation in Construction 17.2 (2008): 122–129.*
9. *Kudo, Shunsuke, et al. "Painting robot with multi-fingered hands and stereo vision." Robotics and Autonomous Systems 57.3 (2009): 279–288.*
10. *Ruchanurucks, Miti, et al. "Humanoid robot painter: Visual perception and high-level planning." Robotics and Automation, 2007 IEEE International Conference on. IEEE, 2007.*
11. *Norzan, Radzi. Drawbot. Diss. UMP, 2007.*
12. *Munna, Mohammed Saifuddin, et al. "Design and implementation of a drawbot using Matlab and Arduino Mega." Electrical, Computer and Communication Engineering (ECCE), International Conference on. IEEE, 2017.*

13. *Aguilar, Carlos, and Hod Lipson. "A robotic system for interpreting images into painted artwork." International conference on generative art. Vol. 11. 2008.*
14. *Chen, Heping, Thomas Fuhlbrigge, and Xiongzi Li. "Automated industrial robot path planning for spray painting process: A review." Automation Science and Engineering, 2008. CASE 2008. IEEE International Conference on. IEEE, 2008.*
15. *Diao, X. D., S. X. Zeng, and Vivian WY Tam. "Development of an optimal trajectory model for spray painting on a free surface." Computers & Industrial Engineering 57.1 (2009): 209–216.*
16. *Lin, Chyi-Yeu, Li-Wen Chuang, and Thi Thoa Mac. "Human portrait generation system for robot arm drawing." Advanced Intelligent Mechatronics, 2009. AIM 2009. IEEE/ASME International Conference on. IEEE, 2009.*
17. *Fa-zhong, Li, Zhao De-an, and Xie Gui-hua. "Trajectory optimization of spray painting robot based on adapted genetic algorithm." 2009 International Conference on Measuring Technology and Mechatronics Automation. 2009.*
18. *Wang, Chuan-sheng, Hui-juan Li, and Rui-qin Wang. "Study of the Wall-Climbing Robot for Hull Painting." E-Product E-Service and E-Entertainment (ICEEE), 2010 International Conference on. IEEE, 2010.*
19. *Moura, Leonel. "A new kind of art: The robotic action painter." X Generative Art Conferece, Politecnico di Milano University (2007).*
20. *Coen Cagli, Ruben, Paolo Coraggio, and Paolo Napoletano. "DrawBot: a bio-inspired robotic portraitist." Digital Creativity 18.1 (2007): 24–33.*
21. *Chen, Hong, et al. "Example-based composite sketching of human portraits." Proceedings of the 3rd international symposium on Non-photorealistic animation and rendering. ACM, 2004.*
22. *Tresset, Patrick, and F. Fol Leymarie. "Generative portrait sketching." Proceedings of VSMM. Vol. 5. 2005.*
23. *Hirano, Yutaka, Ken-ichi Kitahama, and Shintaro Yoshizawa. "Image-based object recognition and dexterous hand/arm motion planning using rrts for grasping in cluttered scene." Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on. IEEE, 2005.*
24. *Lu, Yan, Josh HM Lam, and Yeung Yam. "Preliminary study on vision-based pen-and-ink drawing by a robotic manipulator." Advanced Intelligent Mechatronics, 2009. AIM 2009. IEEE/ASME International Conference on. IEEE, 2009.*
25. *Ruchanurucks, Miti, et al. "Robot painter: from object to trajectory." Intelligent Robots and Systems, 2007. IROS 2007. IEEE/RSJ International Conference on. IEEE, 2007.*
26. *Ďurina, Dušan, Pavel Petrovič, and Richard Balogh. "Robotnačka–The drawing robot." Acta Mechanica Slovaca., In Acta Mechanica Slovaca 10 (2006): 113–116.*
27. *Zivanovic, Aleksandar. "The development of a cybernetic sculptor: Edward Ihnatowicz and the Senster." Proceedings of the 5th conference on Creativity & cognition. ACM, 2005.*
28. *Kwok, Ka Wai, Yeung Yam, and Ka Wah Lo. "Vision system and projective rectification for a robot drawing platform." Control and Automation, 2005. ICCA'05. International Conference on. Vol. 2. IEEE, 2005.*
29. *Hamori, Akos, Janos Lengyel, and Barna Resko. "3DOF drawing robot using LEGO-NXT." Intelligent Engineering Systems (INES), 2011 15th IEEE International Conference on. IEEE, 2011.*
30. *Augello, Agnese, et al. "A cognitive approach for a humanoid painter."*

31. *Jain, Shubham, et al. "A force-controlled portrait drawing robot." Industrial Technology (ICIT), 2015 IEEE International Conference on. IEEE, 2015.*
32. *Birajdar, H. S., & Pawar, M. S. (2013). Development of Rules for Method Selection for the Surfaces of Machining Cylindrical Part to Facilitate Computer Aided Process Planning (CAPP) for Jobbing Type Manufacturing Industries. International Journal of Research in Engineering & Technology, 1(4), 13-28.*
33. *Lau, Meng Cheng, et al. "A portrait drawing robot using a geometric graph approach: Furthest Neighbour Theta-graphs." Advanced Intelligent Mechatronics (AIM), 2012 IEEE/ASME International Conference on. IEEE, 2012.*
34. *Junyou, Yang, et al. "Behavior-based control of brush drawing robot." Transportation, Mechanical, and Electrical Engineering (TMEE), 2011 International Conference on. IEEE, 2011.*
35. *Coeckelbergh, Mark. "Can Machines Create Art?." Philosophy & Technology 2016): 1-19.*
36. *Pérez-Gaspar, Luis-Alberto, et al. "Curve fitting using polygonal approximation for a robotic writing task." Electronics, Communications and Computers (CONIELECOMP), 2015 International Conference on. IEEE, 2015.*